1 Calibration Pulser System (WBS 1.2.1.5)

1.1 Overview

The ability to calibrate the DØ calorimeter electronics is of prime importance to determine with optimal precision the energy of a particle, since a non uniform response degrades both the scale and the resolution of the measurement. In order to perform precision measurements such as the W mass, variations of the calorimeter response as a function of position should be kept as small as possible, to keep the constant term in the resolution small and to minimize biases. There are various causes for variations in channel-to-channel response, such as the tolerance of the preamplifier feedback capacitor, the gain sensitivity to temperature or the non linearity of the response, that the on-line electronic calibration has to correct for.

In Run I, the constant term appearing in the electromagnetic energy resolution was measured to be ~ 1 %. Using the W mass measurement as a benchmark, we would like to calibrate the electronics to better than 2% in Run II in order to have the scale of the constant term set by the other sources of electron energy smearing. For electrons produced from W and Z decays, the stochastic term in the energy resolution is about 2%. The width of the Z° Breit-Wigner line shape, which influences the statistical precision of the Z° mass measurement is about 2.8%. Hence below 2%, the constant term will not represent the dominant source of electron energy smearing.

The method used to calibrate the electronics involves supplying a precise charge pulse of known value to each preamplifier input in a repeatable manner. The level of charge must be adjustable to cover the entire dynamic range of the electronic. A fast shaping time requires a precise control of the calibration signal shape. The charge delivered to the preamplifier serves as both a calibration signal and an indicator of the functionality of each channel. The pulses are channeled to small portions of the electronics in a pattern which will aid in diagnostics of dead or bad channel for instance.

1.2 Run I Calibration system

Twelve pulser calibration systems were used to cover the entire calorimeter in Run I. One of this typical system is shown in fig. 1. Each preamplifier box had its own calibration system hardware. These so-called "charged line" pulsers were providing a pulse of fixed amplitude and width. Each pulser was connected to the load via attenuator, filter, switch and fanout transformer. The voltage signal produced at the load was used to inject charge into the preamplifier input through a precision resistor. The pulser produced a 400 ns wide pulse whose maximum amplitude was 135 V into 50 Ω at a rate of 1 kHz. This output pulse signal was rectangular with a rise and fall time of about 10 ns. Each preamplifier box had 32 distinct paths to which the pulse could be channeled. Mercury-weteed reed relays were used to provide desired paths, providing a repeatable and reliable connection to each position selected. In Run I, a single pulse was hitting simultaneously 144 preamplifiers.

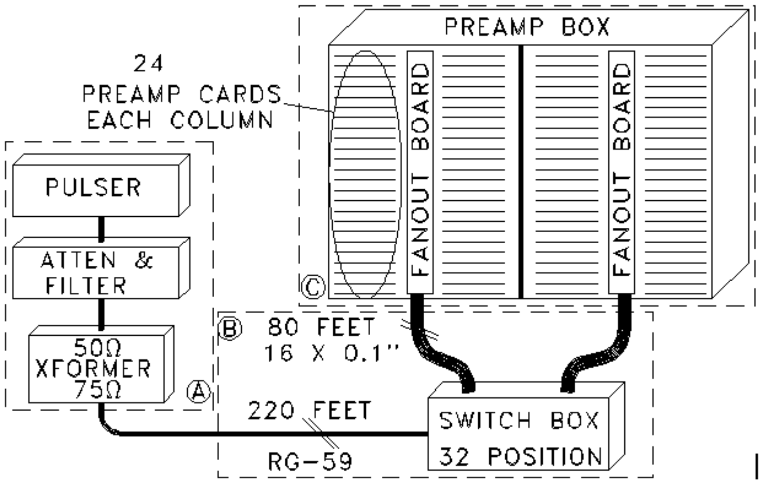

Figure 1: *Calibration system used in Run I*

1.3 Modifications for Run II

This calibration hardware has to be modified in order to perform the necessary functions in Run II. The most important modification is the significant reduction of the injection resistor value in order to reduce the influence of its parasitic capacitor which becomes larger with the shorter shaping time. Indeed a sizeable charge is injected via the uncontrolled parasitic capacitance, and the simulation shows that a 0.25pF variation on this parasitic capacitance gives in the Run II conditions an unacceptable 23 % signal variation on the signal amplitude when using the original 500kΩ injection resistor but less than 0.1 % variation with a reduced 20kΩ resistor.

Other modifications have to cope with the fact that reflections in the pulse distribution system due to imperfect termination and cable attenuations due to skin effect will create in the Run II conditions larger variations in the amount of charge delivered to the preamplifiers. The injection resistor will be reduced to 20kΩ (for preamplifiers with 10pF feedback capacitor), and 40 kΩ (for the 5pF ones). These resistor values allow for the use of low voltage calibration signals (5 V instead of the original 135 V), which are easier to generate accurately. In order to prevent any reflection, the calibration signal will be produced as close to the preamplifiers as possible and will travel only along a 1ns cable. Since it is impossible to inject the calibration signal just across the detector, but only at the preamplifier input, it is important to control accurately the signal shape in order to reduce the sensitivity of the calibration to the basic hardware parameters such as the cable and preamplifier impedance. The difficulties come from the fact that the calibration current is split in two parts : one which goes directly into the preamplifiers and another one which goes into the cable to the electrode and bounces back after twice the cable delay. This results in a different signal shape and a different sensitivity to the cable impedance and length, preamplifier input impedance or detector capacitance (some of these parameters can also vary with temperature or time). These effects have been evaluated in the simulation, showing that it is possible to find a pulse which exhibits similar sensitivity to these parameters as it is summarized in table I. Eventually it might prove necessary to use a table to correct accurately for the cable length.

1.4 Run II calibration system

The D0 calorimeter Run II calibration system will consist in twelve identical subsystems. Each of them is composed of one **pulser motherboard** which sends commands and dc currents to two **active fanouts** which are replacing the previous passive ones and are located as before in the preamplifier boxes. The pulser motherboards are connected via a serial bus to a VME IO register in order to control the amplitude and delay of the calibration signal and to select the pulsed channels. The bus is made of 4 lines: one enable which initiates the handshake, one strobe, one "data in" to write in the modules and one "data out" to read them.

Pulser Motherboard

Each board includes:

- one serial bus interface.
- one channel enable register.
- one eighteen bits DAC.
- six programmable delays.
- ninety six DAC controlled current generators.

On the reception of the trigger, three delayed commands are sent to each active fanout. Commands are differential ECL signals and are sent in the existing 75 ohms cables. 48 controlled currents are sent to each active fanout via shielded twisted pairs cables. The main advantage of this scheme is that only dc currents and logic signals are sent via long cables. The calibration pulses are generated on the active fanout boards near the preamplifiers. The voltage to current conversion is performed with a low offset opamp, a Darlington transistor and a 0.1% precision resistor. The current can be switched off with an enable level from the register.

Active Fanout

Each active fanout is divided in three identical parts. Each part receives one command and sixteen dc currents. One third of active fanout is made of an ECL to TTL translator and sixteen switch daughter boards. On the reception of the command, one switch board delivers 2 calibration signals. The TTL signal steers the DC current in the NPN transistor to ground, turning off the PMOS, which produces a current step across the inductor of the same amplitude as the DC current. This step is shaped by R1, C1 and R2, C2 in order to produce a rising and decaying exponential pulse, within a wide range, and can still once the shaping of the calorimeter signal will be finalized. Thus, the amplitude and shape are controlled by only 2 resistors and 2 capacitors which will be trimmed to better than 1 %. The inductor value is chosen large enough (1 mH) not to affect the pulse shape. Each calibration signal is sent via a short (1 ns)cable to 4 preamplifier boards, hitting 6 preamplifiers on each. Thus, one pulser talks to 48 preamplifiers.

1.5 Plans and Schedule of the Hardware

A first prototype of the pulser system is under development, it consists in a 8 channels pulser mother board with one 16 bit DAC and two programmable delays, and the corresponding active fanout and switch boards. In a first step, the serial bus will be directly emulated by a PC and a LabView programmable digital input output interface. Two prototypes will be done by the middle of May 98, and tested in Orsay and Paris labs. After this step, a test at Fermilab will be carried out in fall 98. It will involve six of these prototypes, which will command one complete active fanout for a total of 1536 calorimeter channels. First tests of the calibration software will also be performed at that time. After successful completion of the test the production phase will start and is foreseen to be completed by summer 99.

1.6 Software Treatment of the On-line Calorimeter Data

Mrinmoy's sections